

February 13, 1896.

Sir JOSEPH LISTER, Bart., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

The following Papers were read :—

- I. "On the Behaviour of Argon and Helium when submitted to the Electric Discharge." By J. N. COLLIE, Ph.D., F.R.S.E., and WILLIAM RAMSAY, Ph.D., F.R.S. Received February 4, 1896.

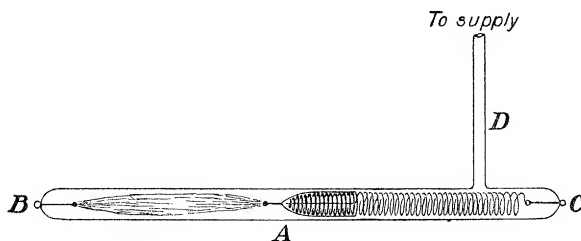
The experiments to be described fall into two classes; the first series relates to the distance through which electric sparks from an induction coil will strike through argon and through helium at atmospheric pressure contrasted with the length of the spark-gap in other gases; and also with the pressures at which the spark-discharge changes into a ribbon-like discharge in different gases. The second series, which was made with the object of ascertaining how much of one gas is detectable in its mixture with another, at different pressures, deals with the spectra of gases in electrodeless vacuum tubes. As both sets of phenomena relate to the passing of electric discharge through gases, we have thought it well to consider them together.

The attention of one of the authors was drawn to the spark-gap, as a possible means of obtaining information regarding the atomicity of argon and helium, by Mr. Natterer, who was kind enough to send copies of his paper on the subject ('Wied. Ann.,' 1889, p. 663). Natterer's conclusion, drawn from a great many experiments, was that the spark-gap at atmospheric pressure varied in length inversely as the atomicity of the gas; thus, in mercury gas, which is acknowledgedly monatomic, the distance traversed by a spark from electrodes of approximately constant potential, was very much greater than in diatomic gases, such as oxygen, hydrogen, nitrogen, or carbon monoxide; and in these, greater than in gases of more complex molecular structure. Our experiments show that while with argon, the distance traversed by the spark is considerably greater than with air, oxygen, or hydrogen, with helium the spark is capable of passing through most unusual distances.

To carry out such experiments the tube must contain movable

electrodes; and yet, in order to avoid contamination of the gases, they must have sealed joints. Closing with india-rubber corks appeared to work well in Natterer's experiments; but then he had large quantities of common gases at his disposal. In our experiments this was unfortunately not the case. Our apparatus was, therefore, constructed on the plan shown in the annexed figure. A is a tube

FIG. 1.



about 15 cm. in length, and 0·8 cm. internal diameter. A fixed platinum electrode, fused into a knob at the end, was sealed through the glass at B. The wire at C was attached to a long spiral of very thin copper wire, which was soldered to a platinum electrode with a knob. In order to be able to alter the position of this electrode, it was enclosed in a thimble of glass, which contained a roll of soft iron wire, as shown at A. The position of this electrode could be altered by means of a magnet; and if close to A or to C, it moved on tapping the tube gently, for the copper spring extended, or shortened itself, if compressed or pulled out beyond a place of rest in the middle of the tube. Gas was introduced into the vacuum tube through D; a phosphorescent vacuum having previously been made by means of a Töpler's pump; the tube was washed out once or twice with the gas, before each experiment.

The current was an intermittent one from one of Apps' large induction coils, driven by a storage cell giving about 8 volts. The hammer of the coil was not altered in position during the experiments.

It was found impossible to make measurements of the extreme possible length of a spark. After the coil had been running for some time, an isolated spark generally passed, even when the electrodes were far apart. But consistent measurements could be obtained when a rapid discharge began to occur on bringing the electrodes together. It was found possible to obtain constant readings of distance to within half a millimetre; and to form an accurate estimate of the intensity of the rain of sparks, as contrasted with intermittent discharges.

The mean results are as follow :—

Oxygen.....	23·0 mm.
Air	33·0 „
Hydrogen	39·0 „
Argon	45·5 „
Helium.....	probably 250 or 300 mm.

The tube was not long enough to obtain measurements with helium. But another tube with permanent electrodes, distant from each other 200 mm., gives, not sparks, but a ribbon of flame, due apparently to the luminosity of the first spark remaining until the second has begun its journey. This band is of a blue colour, and does not show the yellow D_3 line very brightly. The other helium lines are much more brilliant. Indeed, the D_3 line is not a marked feature of the helium spectrum at high pressure, with an unaided Ruhmkorff coil discharge.

As regards the purity of the samples of gas employed, it is sufficient to mention the method of preparation. The oxygen was made by heating potassium permanganate in a small test-tube; the air having been expelled until the nitrogen spectrum had faded out, a large test-tube was filled with the gas over mercury, and several times washed out. The third or fourth filling was taken for experiment. During the pumping empty of the experimental tube, it could be seen that at low pressure, none of the characteristic nitrogen bands were visible. The air was ordinary air, free from carbon dioxide, dried by passage through phosphoric anhydride; all the gases were dried thus on their way into the experimental tube; and the absence of the hydrogen lines in the case of argon and helium showed water-vapour to be absent. It will afterwards be shown what a small percentage of hydrogen is recognisable. The hydrogen was prepared from charged palladium, and gave a pure spectrum. The argon had been sparked down with oxygen and soda, the excess of oxygen having been removed with hot phosphorus. The helium had been circulated over red-hot magnesium until it gave a pure spectrum.

It will, we think, be acknowledged that the length of spark in helium is a very remarkable phenomenon. To what is it to be attributed? Any attempt to answer this question must necessarily, in our ignorance of what takes place during passage of discharge through gases, be of a speculative character. And inasmuch as it is probably connected with other properties of helium, we shall postpone our attempt at an explanation until our further experiments have been described.

After these experiments had been made it was discovered that the spark discharge changes to a ribbon discharge at some definite pressure with all gases. The discovery was an accidental one. We wished

to repeat the experiments on the helium ribbon, and the tube was filled with the first sample of helium that came to hand; it had been prepared from bröggerite, and had received some contamination from air and nitrogen. To our surprise, we failed to obtain a ribbon discharge at ordinary atmospheric pressure; only a rain of sparks could be seen, and it was not until the pressure had been lowered by several hundred millimetres that the discharge became ribbon-like. This observation led to the experiments, of which we now give an account.

The distance between the electrodes was arranged at 170 mm.; the hammer of the coil was fixed in a definite position, and a freshly charged accumulator of 8 volts was employed to drive the coil. The first gas experimented with was dry pure air.

1. <i>Air</i> .—Spark began to pass feebly at a pressure of..	117 mm.
The band was continuous, but “fluffy” at ..	70 „
The continuous band began to disappear at..	83 „
On removing air, the continuous band was visible at	74 „

The pressure appears to be 73 or 74 mm., at which the change first occurs. On lowering pressure still further, the band grows less well-defined, and finally fills the tube as a luminous discharge, such as is seen in an ordinary vacuum-tube.

2. <i>Hydrogen</i> .—Sparking at.....	57 mm.
Band visible at	42 „
Becoming indistinct at edges at	22 „
Very “fluffy” at	14 „
Again giving sparks at.....	43 „

The pressure in this case appears to be 42 or 43 mm.

3. <i>Oxygen</i> .—The band was clear, but quite continuous at	33 mm.
On raising pressure, intermittent sparks appeared at	86 „
Band began to be free from sparks at.....	81 „
Band disappeared again, and sparking began at	86 „

The pressure of the oxygen appears to be somewhat above 81 mm. to produce the looked-for change in character. The amount of luminosity was very feeble.

4. <i>Carbon Dioxide</i> .—Continuous band at.....	92 mm.
Distinct sparking at.....	102 „
On reducing pressure, sparking ceased at	94 „

Here the critical pressure appears to be 92—94 mm.

5. *Cyanogen*, prepared by heating mercuric cyanide. During the passage of the spark, decomposition occurred, and the tube was covered with a thin film of a brownish deposit. The results may have been vitiated by this, but the difference in behaviour is still very striking.

The band was broad and continuous at..... 23 mm.

On increasing pressure, sparking occurred at 24 „

6. *Nitrogen*.—The nitrogen was made from air by withdrawing oxygen with phosphorus; it therefore contained argon. The transition with nitrogen was very difficult to observe. The band was always ill-defined. The results are probably little to be trusted.

Sparks 59 mm.

No sparks; ill-defined “fluffy” band.... 31 „

Sparks beginning; band still visible.... 34 „

It may be taken that the point looked for lies between 31 and 34 mm., say 33 mm.

7. *Carbon Monoxide*.—Prepared from formic acid treated with sulphuric acid. The transition was very clear.

Continuous band, somewhat “fluffy”.... 49 mm.

Sparks beginning at 50 „

8. *Helium*.—Free from hydrogen and nitrogen. Showed pure spectrum. Gas extracted from bröggerite.

Continuous band 766 mm.

Sparks seen intermittently 1310 „

Sparks ceased and band reappeared .. 1270 „

These results are summed up in the following table:—

Gas.	Pressure of changes of character of discharge.
Air	73 or 74 mm.
Hydrogen.....	42 or 43 „
Oxygen... ..	81 „
Carbon dioxide	92 or 94 „
Cyanogen	23 „
Nitrogen.....	33 „
Carbon monoxide	49 „
Helium.....	1270 „

These phenomena are, without doubt, very complex; but one fact is unmistakable: that helium presents a behaviour very different

from that of all other gases. In short, a tube like those termed "Pffücker's tubes," need not be filled with helium at a low pressure, but shows all the phenomena of a vacuum-tube at ordinary atmospheric pressure. The order of arrangement of the other gases, moreover, is not the same as that which obtains with the shower of sparks passing through the gas. This may be due to some molecular change due to lowering of pressure; but such a supposition is of a purely speculative character.

Our next series of experiments relate to the visibility of the spectrum of one gas in presence of another. The gases employed were hydrogen, oxygen, nitrogen (atmospheric), argon, and helium; our primary object was a practical one—to ascertain whether the spectrum affords an adequate test of the purity of the gases. For example, if the spectrum of nitrogen is no longer visible in a mixture of argon and possibly nitrogen, can it be assumed that nitrogen is wholly absent? How much must the percentage of nitrogen in such a mixture be reduced before the spectrum disappears?

To follow how these experiments were carried out, a figure of the apparatus employed is necessary, and a detailed description may prove helpful to others willing to make a similar inquiry.

The Töpler pump A (fig. 2), with connection tube B, and drying tube C (filled with phosphorus pentoxide), had a volume of 290 c.c. up to the stopcock D. The rest of the apparatus, including connecting tube E, drying tube F, vacuum tube G, and tubes down to stopcock. H had a volume of 57.5 c.c. The ratio of the total volume to the volume of the vacuum tube, &c., is nearly 6 : 1, and, as extreme accuracy is not here necessary, it will be taken that, on allowing gas to pass the stopcock D and enter the pump, its volume will be increased and its pressure diminished in the proportion of 1 : 6.

The vacuum tube G was without electrodes; its wide portions were covered with tinfoil, and connection was made with the coil by loops of wire twisted round the foil.

The method of introducing the gases requires description. H is a two-way stopcock, and the exit-tubes were curved round and stood in a mercury trough, I. Their ends (one of which is shown at K) were drawn out and bent over as shown in the small figure (3), and a slight scratch with a glass-cutter was made at the bend. The little tubes shown in fig. 2 at K were, at a separate mercury trough, filled with the required gases, after being washed out by introducing a few bubbles of the gas in question; they were then transferred to the trough I, and placed in the position shown. The whole apparatus was next pumped free of air; the nitrogen spectrum fades, and finally a vacuum is obtained through which a spark will not pass; the spark prefers to strike across between the coatings

FIG. 2.

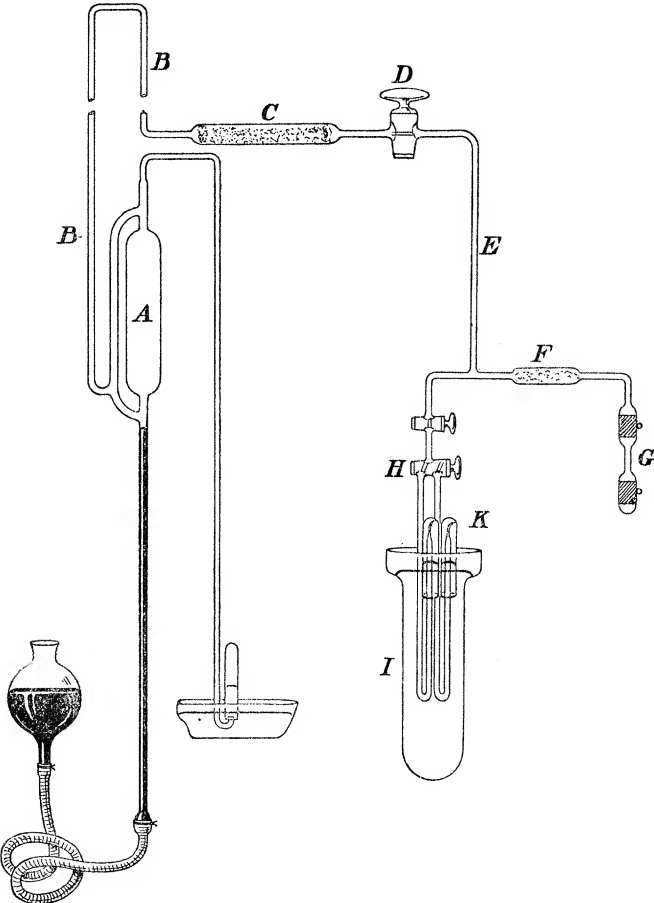


FIG. 3.



of tinfoil, through the air. The stopcock H was then shut, and by pressing down the little reservoirs on the capillary tubes, the latter broke at the scratches, and each U-tube became filled with the gas contained in the reservoir placed over it. The stopcock above H was then shut, and by opening H a charge of gas entered the space between the two stopcocks. H was again shut, and the upper stopcock opened (D being shut), and the charge of gas filled the vacuum tube, being dried by passage through the pentoxide contained in F. It should here be remarked that the gases underwent a preliminary drying by contact with fragments of solid potash in the little reservoirs at K. The charge of gas in the vacuum tube was, after a short time, removed by pumping until its spectrum disappeared and the vacuum tube ceased to conduct. This process was repeated several times as a precautionary measure.

The space between the stopcock H and the one above it held 0.066 c.c.; hence it was possible to introduce that amount or any multiple of it into the vacuum tube, and when required, by opening the stopcock communicating with the pump, to remove five-sixths of that amount, leaving 0.011 c.c. in the vacuum tube; and as this could be done with either gas, it was possible to alter both quantity and pressure at will.

The first set of experiments was made with helium and hydrogen. The pump and vacuum tube were empty after washing with helium.

1. 0.066 helium; 0.066 hydrogen in 57.5 c.c.

P = 1.74 mm.

The hydrogen red was brilliant, the blue strong, the violet visible.

The helium red faint, the yellow visible, the green faint, the violet doubtful.

2. 0.066 helium; 0.132 hydrogen in 57.5 c.c.

P = 2.61 mm.

Helium spectrum invisible.

Volume increased to 347.5 c.c.

P = 0.43 mm. Helium spectrum strong; reds visible.

P = 0.072 mm. Helium spectrum very strong; reds comparable with hydrogen red in intensity.

P = 0.012 mm. Helium relatively stronger.

P = 0.00033 mm. Both very faint, but still visible.

It is thus seen that while at moderately high pressure one part of helium in two parts of hydrogen is not detectable, on reducing pressure the brilliancy of the helium increases relatively to that of hydrogen. These spectra were examined with direct-vision prisms: the narrow part of the vacuum tube served for slit. The great advantage

of this method of viewing the spectrum is the very small absorption of light; the spectrum is exceedingly brilliant.

The secondary spectrum of hydrogen was very conspicuous in these experiments; it consists of a great number of lines in the red, red-orange, and yellow. It appears to be brought out by the electrodeless tube.

3. 0.066 helium; 0.264 hydrogen in 57.5 c.c. Helium invisible.

P = 0.73 mm. Helium yellow just visible; green fairly strong.

On reducing pressure, the helium gained in strength. The red came out at a pressure of 0.12 mm., but it did not become equal to the hydrogen-red in intensity on further reduction of pressure.

4. 0.066 helium; 0.66 hydrogen. No helium visible.

P = 1.45 mm. Helium green faintly visible; yellow almost extinct.

P = 0.24 mm. A little more distinct, but still very faint.

It appears possible, therefore, to detect 10 per cent. of helium in hydrogen at low pressures; but a smaller percentage would not be seen. Interposing a spark gap or jars made no appreciable difference in these spectra.

The second set of experiments had for its object to ascertain how much hydrogen could be detected in helium. Without entering into details, it may be stated that the smallest trace of hydrogen can be detected in helium. Actually the proportion was reduced to about 1 part of hydrogen in 100,000 of helium, and the hydrogen lines were still easily recognised.

The third set of experiments related to a mixture of nitrogen and helium. Knowing that a very small amount of nitrogen could be detected in a large amount of helium, the first charge of nitrogen was reduced to 0.002 c.c. in 57.5 of space by emptying the pump, after the stopcock had been left open for about ten minutes; for experience has shown that the flow of gas from one part of the apparatus to another is very slow at small pressures. The results were obtained in the same manner as before, and are tabulated below.

Nitrogen, 3.0	p. c. at 0.90	mm. pressure.	Strong.
"	0.4	" 1.02	" "
"	0.4	" 0.17	" "
"	0.07	" 1.04	" Nitrogen still visible.
"	0.07	" 0.17	" "
"	0.011	" 1.02	" "
"	0.011	" 0.17	" Almost gone.

The next charge of helium reduced the percentage of nitrogen

to 0.002, and its spectrum could not be detected. Hence somewhat less than 1 part of nitrogen in 10,000 of helium can be detected.

In endeavouring by the fourth set of experiments to establish how small a proportion of helium could be detected in nitrogen, we were unable to recognise the D_3 line on account of its coincidence with one of the yellow nitrogen bands. But the helium green is not interfered with, and it was therefore looked for. The results were :—

Helium, 50.0 p. c. at 1.67 mm. pressure.	Green visible.
„ 50.0 „ 0.28 „	Easily „
„ 22.0 „ 1.28 „	Green just visible.
„ 22.0 „ 0.21 „	Yellow just visible ; green stronger.
„ 22.0 „ 0.03 „	Both intensified.
„ 12.5 „ 1.16 „	Green invisible.
„ 12.5 „ 0.19 „	Green just visible.
„ 12.5 „ 0.03 „	Yellow „

Hence it may be concluded that it is not easy to detect 10 per cent. of helium in nitrogen, even at low pressures.

The fifth set of experiments relates to the detection of argon in helium.

Argon, 50.0 p. c. at 1.67 mm. pressure.	Argon bright ; helium faint.
„ 12.5 „ 1.16 „	Argon bright.
„ 2.3 „ 1.28 „	Argon still bright.
„ 2.3 „ 0.21 „	Argon still bright ; the green group especially ; the reds still visible.
„ 0.76 „ 1.04 „	Argon orange and greens faintly visible.
„ 0.06 „ 1.04 „	Argon still faintly visible.

It is seen that 1 part of argon in 2,000 of helium is still detectable. The orange line and the first green group of the argon spectrum are very persistent. Introduction of a spark-gap here causes the argon spectrum to change to blue, and a number of blue lines become visible, without, however, much interfering with the brilliancy of the orange and green lines.

The sixth set of experiments was directed to ascertain how much helium could be detected in argon.

Helium, 50 p. c. at 1.67 mm. pressure.	Both easily visible.
„ 33 „ 2.62 „	Helium barely visible.

On reducing pressure by pumping, the helium spectrum strength-

ened, and then faded out, while the argon spectrum persisted after all helium had disappeared.

Helium, 25 p. c. at 3.49 mm. pressure.	Helium invisible.
" " " 0.58 "	Still invisible.
" " " 0.09 "	D ₃ very faint.
" " " 0.015 "	Stronger.

It therefore requires a low, but not a too low, pressure, to render 25 per cent. of helium visible in argon; for on still further reducing pressure the helium disappeared, leaving the argon spectrum visible, though faint.

The seventh set of experiments deals with argon and nitrogen.

Nitrogen, 14.3 p. c. at 1.02 mm. pressure.	Both easily visible.
" 2.6 " 1.04 "	Nitrogen strong.
" 2.6 " 0.17 "	Nitrogen faint.
" 0.42 " 1.05 "	Nitrogen visible.
" 0.42 " 0.17 "	Nitrogen gone.
" 0.08 " 1.05 "	Nitrogen just visible.
" 0.08 " 0.18 "	Nitrogen gone.

One part of nitrogen is therefore visible in 1,250 parts of argon at a pressure of 1 mm.; but, on reducing pressure, its spectrum fades.

The eighth set of experiments were directed to ascertain how little argon is visible in nitrogen. With 37 per cent. of argon, the reds at the least refrangible end of the spectrum were still visible but very faint; the green group was absent; and the conspicuous orange could not be distinguished on account of the nitrogen bands. After exhausting by several strokes of the pump, the reds became more distinct, but the other lines were not seen, on account of the interference of the brilliant nitrogen spectrum. It is doubtful whether argon would be seen if a lower percentage were present.

The ninth set of experiments were undertaken to see whether the presence of oxygen affected the spectrum of argon. With 2.3 per cent. of argon, at a pressure of 1.04 mm., the argon reds were invisible, and the brilliant green group appeared as a luminosity, but could not be distinguished as separate lines. The effect of oxygen is greatly to decrease the luminosity of the argon spectrum, so that it is difficult to tell whether it is visible or not. Even a very small quantity of oxygen has this effect. The reduction of pressure has no effect in intensifying the spectrum. It gradually grows fainter, and disappears.

The reduction of pressure alters the spectrum of pure helium in a very remarkable way. The yellow line becomes less brilliant in comparison with the green. This is not produced, as stated by Professor Runge at Ipswich, by diffusion of one constituent of helium

away from another; but as he himself has acknowledged in a private letter, by the cause which we ascribe. From the experiments detailed above, the relative strengthening of the green line may, however, well be due to the persistence of that constituent of the gas which shows the green line; although at present we hold it as unproved that what is termed helium is a mixture. It may, however, be taken as confirmatory of that view that, for instance, the spectrum of nitrogen is invisible in argon, if 0.42 per cent. of the former is present at a pressure of 0.17 mm.; and yet at a pressure of 1.05 mm. as little as 0.08 per cent. of nitrogen is visible. In a mixture of nitrogen and argon, increase of pressure increases the brilliancy of the nitrogen spectrum; and it may be argued that increase of pressure brings out the yellow constituent of helium, leaving the luminosity of the green unchanged.

The results of these experiments are summed up in the short table which follows.

Amount of Gas Detectable in a Mixture.

(1) Helium in hydrogen.	33.0	p. c. of helium invisible at 2.61 mm.
" "	10.0	p. c. of helium barely visible at lowest pressure.
(2) Hydrogen in helium.	0.001	p. c. of hydrogen visible at all pressures.
(3) Nitrogen in helium.	0.01	p. c. of nitrogen almost invisible.
(4) Helium in nitrogen.	10.0	p. c. of helium difficult to detect.
(5) Argon in helium.	0.06	p. c. still visible at all pressures.
(6) Helium in argon.	33.0	p. c. invisible at 2.62 mm. pressure.
" "	25.0	p. c. invisible at 0.58 mm. pressure.
(7) Nitrogen in argon.	0.42	p. c. invisible at 0.17 mm. pressure.
" "	0.08	p. c. invisible at 0.18 mm. pressure, though just visible at 1.05 mm.
(8) Argon in nitrogen.	37.0	p. c. barely visible at any pressure.
(9) Argon in oxygen.	2.3	p. c. difficult to distinguish at 1.04 mm. pressure.

Broadly stated, these experiments show that while relatively large amounts of helium and argon require to be present in hydrogen and nitrogen before their spectra become visible, an exceedingly minute amount of hydrogen or nitrogen is visible in helium or argon; and that a rise of pressure increases the visibility of nitrogen, both in

helium and argon. Also that a large proportion of helium must be added to argon to become visible; while a minute trace of argon is visible in helium. And combining these results with those relating to the *spark-gap* or to the continuous discharge, it would appear that at atmospheric pressure, a discharge passes much more readily through helium than through the other gases, while at very low pressures, if conveyance of current can be inferred from luminosity of spectrum, the current passes more readily through all other gases than through helium; and that a current is conveyed more readily by nitrogen than by argon.

In the present state of our ignorance on what occasions the passage of current through gases, it is perhaps premature to speculate. But, accepting the hypothesis which appears to be gaining ground, namely, that a species of electrolysis takes place during the passage—a tentative explanation may be put forward. It may be supposed, as Hr. Lang has pointed out (*“Dielectricitätsconstante,” Wied. Ann.,* 56, p. 543) that a gas, such as hydrogen, at atmospheric pressure, is partially, but very slightly, ionised, or perhaps better, polarised, if that expression refers to atoms capable of receiving and transmitting an electrical charge.

Now, the conveyance of the current is conditioned by at least two circumstances—first, by the number of such atoms per unit volume; and second, by their relative velocity, which may be taken as proportional to the square root of the density of the gas. Hence, it might be inferred that if only few atoms are present, great resistance will be offered—first, because of their fewness; second, because of the frictional resistance offered by the molecules of gas, as distinct from the atoms. It is not so easy to understand why a high electromotive force is required to overcome this resistance, unless it be supposed that the atoms capable of conveying charges neutralise each other by combination before the charge can be transmitted from one electrode to the other. Waiving this difficulty for the present, the hypothesis agrees with the known fact, that decrease of pressure promotes dissociation, where the number of ions or molecules produced by dissociation is greater than the original number of undissociated molecules; and with increased dissociation there should be, as there appears to be, decreased resistance in the case of diatomic gases, such as hydrogen, oxygen, and nitrogen.

In considering gases, presumably monatomic, such as argon and helium, we see that the former offers considerably less resistance to the discharges at atmospheric pressure than the diatomic gases; and the latter very much less. These peculiarities may be due to their monatomic character, and the great difference between the length of the *spark-gap* in argon and in helium may be dependent on their difference of densities, and be connected with the length of the mean

free path of their molecules. When pressure is lowered these gases appear to conduct less well than the diatomic gases; and it may be that their molecular constitution is less affected, if affected at all, by diminution of pressure.

The behaviour of mixtures of argon and helium at low pressures is somewhat inscrutable. Why should argon convey current almost to the exclusion of helium, if, indeed, visibility of its spectrum be taken as an indication of conductivity? In this respect argon rather resembles the diatomic gases.

It may be objected that, in making such observations, one consideration has been neglected. It is the nature of the electrodes. This may indeed play a not unimportant part in the phenomena. It is unquestionable that hydrogen and helium are both absorbed by platinum, and it would appear that nitrogen, too, can be made to combine, for it is removed from a vacuum tube containing it, if the platinum is "splashed" on to the walls. But the experiments on mixtures of gases were performed in vacuum tubes without electrodes, and the influence of the electrodes comes in only with experiments on gases at atmospheric pressure, and in those in which pressure was reduced. Their pressure may, however, conduce to some kind of polarising influence, and the conclusions, such as they are, may be vitiated by neglecting this factor.

We trust that these somewhat rash speculations will be forgiven; the subject is a difficult one, and we have carried out the experiments more with the view of obtaining practical help in recognising the purity of argon and helium than of carrying out a research on the relative conductivities of gases. There is evidently a wide field for research, and we shall be glad if this description of our methods of manipulation and of the somewhat meagre results which we have obtained may induce others, better qualified than we, to make similar investigations.

II. "On the Generation of Longitudinal Waves in Ether."

By LORD KELVIN, F.R.S. Received February 10, 1896.

In a short note published in last week's 'Nature,' of which a copy is appended, I suggested an arrangement of four insulated and electrified spherical conductors with their centres in one line, giving rise to ethereal waves in the surrounding atmosphere, of which the disturbance in the line of centres is essentially longitudinal. But at any finite distance from this line there must also be laminar or distortional waves of the kind expressed in Maxwell's equations. The object of my present communication is to show an arrangement by which a large space of air is traversed by pressural disturbance, or by waves essentially longitudinal, or by condensational-rarefactional

FIG. 2.

